

CLAIMS

What is claimed is:

1 1. An apparatus for testing a sample for constituents comprising;
2 a plurality of electrochemical sensors, each sensor adapted to detect a different
3 constituent within the sample;
4 a reservoir for containing the sample;
5 a plurality of interconnected channels fluidly coupling the reservoir to the
6 sensors; and
7 a circuit coupled to the plurality of sensors to analyze the electrochemical
8 properties of the sensors to detect the presence of a particular constituent at each
9 sensor.

1 2. The apparatus of claim 1 further comprising a pump fluidly coupled to said
2 reservoir and a plurality of interconnected channels for applying positive pressure to the
3 reservoir and plurality of interconnected channels.

1 3. The apparatus of claim 2 wherein the pump is a micro-pump.

1 4. The apparatus of claim 2 further comprising a microheater coupled to
2 each sensor to heat the sensor.

1 5. The apparatus of claim 2 wherein the circuit for detecting further
2 determines the concentration of the constituent in the sample.

1 6. The apparatus of claim 1 wherein each sensor is adapted to detect a
2 different constituent.

1 7. The apparatus of claim 1 wherein the electrochemical sensors each
2 comprise an electrochemical cell comprising:
3 a working electrode with a coating selected to bind with a particular electro-active
4 constituent;
5 a counter electrode;
6 a reference electrode;
7 filter paper disposed so as to separate between the electrodes from each other;
8 and
9 an electrolyte in said filter paper.

1 8. The apparatus of claim 7 wherein the electrochemical cell further
2 comprises a glass frit disposed between the channels external of the sensor and the
3 electrodes of the sensor and a capillary housing the other elements of the sensor.

1 9. The apparatus of claim 7 wherein the working electrode is disposed
2 closest to the channel through which sample enters the sensor, the counter electrode is
3 disposed furthest from the channel through which sample enters the sensor, and the
4 reference electrode is disposed between the other two electrodes, and wherein the
5 capillary includes an opening disposed adjacent the working electrode through which
6 excess sample can exit the cell.

1 10. The apparatus of claim 1 wherein the circuit comprises analytic circuitry
2 for analyzing the electrochemical properties of the sensors, a multiplexer, and circuitry
3 for controlling the multiplexer to selectively electrically couple the analytical circuitry to
4 each of the sensors, whereby the analytical circuitry can be used to analyze each
5 sensor distinctly.

1 11. The apparatus of claim 10 wherein the circuit is embodied on a single
2 microcircuit.

1 12. The apparatus of claim 10 wherein the analytic circuitry is selectively

2 electrically coupled to the working electrode, reference electrode and counter electrode
3 of each sensor cell and is adapted to apply a series of electrical pulses to the cell and
4 measure the transient responses through the cell to each of the pulses.

1 13. The apparatus of claim 12 wherein the analytic circuitry is further
2 adapted to integrate each current transient response to a pulse and derive electrical
3 charge Q as a function of the magnitude of the corresponding pulse.

1 14. The apparatus of claim 1 wherein the channels are micro-channels.

1 15. The apparatus of claim 7 wherein the coating of the working electrode is
2 adapted to bind with heme molecules.

1 16. The apparatus of claim 15 wherein the coating comprises dithiol.

1 17. The apparatus of claim 16 wherein the working electrode comprises a 25
2 to 100-micron-diameter, 1-meter long gold wire coiled around a 0.25 to 0.5-mm-
3 diameter gold support wire.

1 18. The apparatus of claim 16 wherein the working electrode comprises a
2 powdered gold bound together by adhesive.

1 19. The apparatus of claim 18 wherein the adhesive is a mixture of carbon
2 powder and polytetrafluorethylene adhesive.

1 20. An apparatus for testing a sample for constituents comprising;
2 a plurality of electrochemical sensor cells, each sensor cell adapted to detect a different
3 constituent within the sample; and
4 an analytic circuitry for analyzing the electrochemical properties of the sensors;
5 a multiplexer; and
6 control circuitry for controlling the multiplexer to selectively electrically couple the
7 analytical circuitry to each of the sensors, whereby the analytical circuitry can be used
8 to analyze each sensor distinctly.

1 21. The apparatus of claim 20 wherein the analytic circuit, multiplexer and
2 control circuit are embodied on a single microcircuit chip.

1 22. The apparatus of claim 21 wherein the electrochemical sensors each
2 comprise an electrochemical cell comprising:
3 a working electrode with a coating selected to bind with a particular electro-active
4 constituent;
5 a counter electrode;
6 a reference electrode;
7 filter paper disposed so as to separate between the electrodes from each other;
8 and
9 an electrolyte in said filter paper.

1 23. The apparatus of claim 22 wherein the analytic circuitry is selectively
2 electrically coupled to the working electrode, reference electrode and counter electrode
3 of each sensor cell via the multiplexer and is adapted to apply a series of electrical
4 pulses to the cell and measure the transient responses through the cell to each of the
5 pulses.

1 24. The apparatus of claim 23 wherein the analytic circuitry is further adapted
2 to integrate each current transient response to a pulse and derive electrical charge Q as
3 a function of the magnitude of the corresponding pulse.

1 25. The apparatus of claim 24 wherein the circuit for detecting further
2 determines the concentration of the constituent in the sample.

1 26. The apparatus of claim 21 further comprising a microheater coupled to
2 each sensor cell to heat the sensor cell.

1 27. The apparatus of claim 20 wherein the electrochemical sensors each
2 comprise an electrochemical cell comprising:
3 a working electrode with a coating selected to bind with a particular electro-active
4 constituent;
5 a counter electrode;
6 a reference electrode;
7 filter paper disposed so as to separate between the electrodes from each other;
8 and
9 an electrolyte in said filter paper;
10 wherein each working electrode has the same coating, whereby each sensor
11 tests for the same constituent.

1 28. The apparatus of claim 16 wherein the working electrode comprises a 25-
2 to 100-micron-diameter, 1-meter-long gold wired coiled around a 0.25 to 0.5-mm-
3 diameter gold support wire.

1 29. The apparatus of claim 22 wherein the working electrode comprises a
2 powdered gold bound together by adhesive.

1 30. The apparatus of claim 28 wherein the adhesive is a mixture of carbon
2 powder and polytetrafluorethylene adhesive.

1 31. A method for testing a sample for constituents comprising the steps

2 of:

3 providing a plurality of electrochemical sensors, each sensor adapted to detect a
4 different constituent within the sample;

5 providing a circuit coupled to the plurality of sensors to analyze the
6 electrochemical properties of the sensors to detect the presence of a particular
7 constituent at each sensor;

8 introducing a sample into each sensor; and

9 simultaneously analyzing the electrical properties of each electrochemical sensor
10 to detect the presence of at least one constituent in the sample at each sensor.

1 32. The method of claim 31 wherein each sample is a part of the same larger
2 sample.

1 33. The method of claim 32 wherein each sensor comprises a working
2 electrode with a coating selected to bind with a particular electro-active constituent, a
3 counter electrode, and a reference electrode, and wherein the working electrode of
4 each sensor has a different coating, whereby each sensor can be analyzed to detect a
5 different constituent.

1 34. The method of claim 33 further comprising the steps of:

2 providing a reservoir for containing the sample;

3 providing a plurality of interconnected channels fluidly coupling the reservoir to
4 the sensors.

1 35. The method of claim 34 further comprising the step of:

2 applying positive pressure to force the samples into the plurality of sensors.

1 36. The method of claim 31 wherein each sensor is adapted to detect a
2 different constituent.

1 37. The method of claim 31 wherein a different sample is introduced to each
2 sensor.

1 38. The method of claim 31 wherein the analyzing step further comprises the
2 step of:

3 simultaneously determining the concentrations of the plurality of constituents in
4 the sample at each sensor.

1 39. The method of claim 31 wherein the detecting step comprises the steps of:
2 selectively coupling the circuit to each sensor and analyzing each sensor
3 sequentially.

1 40. The method of claim 31 wherein each sensor comprises a working
2 electrode with a coating selected to bind with a particular electro-active constituent, a
3 counter electrode, and a reference electrode, and wherein the detecting step comprises
4 the steps of:

5 (1) selectively electrically coupling the circuit to the working electrode, reference
6 electrode and counter electrode of one of the plurality of sensors;

7 (2) applying a series of electrical pulses to the cell;

8 (3) measuring the electrical response by the cell responsive to each of the
9 pulses;

1 41. The apparatus of claim 40 wherein the detecting step further comprises
2 the step of:

3 integrating each current transient response to a pulse and deriving electrical
4 charge Q as a function of the magnitude of the corresponding pulse.